Autor: Wolfgang Baader

Rolf Kloss

Titel: Experiences on handling liquid substrates of high solid content in agricultural biogas-plants

Institut: Institut für Technologie, Bundesforschungsanstalt für Landwirtschaft, 1982

Elektronisch veröffentlicht am: 24.05.2012

url: http://www.digibib.tu-braunschweig.de/?docid=000430183

Ursprünglich erschienen:

Simposio International "Advances en digestion anaerobica", 25. - 27. October 1982, Iztapalapa (Mexico)

EXPERIENCES ON HANDLING LIQUID SUBSTRATES OF HIGH SOLID CONTENT IN AGRICULTURAL BIOGAS-PLANTS[1]

W. Baader and R. Kloss

Institute of Technology, Federal Research Centre of Agriculture Braunschweig-Völkenrode(FAL), Bundesallee 50,D-3300 Braunschweig Fed. Rep. of Germany

ABSTRACT

Mixtures of homogenous organic slurry and coarse vegetable matter are characterized by the tendency to separate owing to floatation and by the risk of accumulating of coarse, preferable fibrous matter, causing an uncontrolled flow through the total system followed o blockages. To overcome these fluidmechanical problems in practice preferably the horizontal canal-type digester with mechanical stirring device and the multiple chamber-type digester with hydraulic stirring by gas-displacement are used. As a newly developed solution to achieve in the digester the controlled flow of mixture which tend to separate, a completely filled up-flow loop-digester is described.

KEYWORDS

Anaerobic digester, agricultural wastes, fluidmechanics, floatation, mixing

INTRODUCTION

Starting from two plants remaining from the 50's (one stopped operation in 1980), the number of agricultural biogas plants newly erected in the Federal Republic of Germany has continually risen since 1979. Up to now 58 plants are in operation on farms. A further 19 plants are in an advanced stage of planning or are already being built, so that one can reckon with them commencing operation in 1983.
About two third of these plants are fed with animal wastes without bedding. In those cases the substrate contains only suspended solids of small particle size and of uniform structure but with a very low content of coarse and floatable matter. Hence it can be treated in completely mixed vertical-type or horizontal-type through-flown digesters. The choice of the mixing system depend more on the economic (costs, energy demand, reliability) than on the operational factors, which can be brought to an optimum efficiency by using the various systems as hydraulic circulation, mechanical mixing, gas diffusion, or gaslift-pump. In tank-type digesters predominantely pumps are installed for mixing the substrate.
In about one third of the plants installed up to now in Germany the feedstock for the digester consists in a mixture of liquid manure and dispersed solids, such as chopped straw or vegetable residues. These substrates, however, tend to separate by gravity or floatation, if the viscosity of the liquid phase is low and the particle size of the solids is not reduced so far that the solid matter can be mixed with the liquid to a homogeneous fluid. Obviously such an extrem disintegration of the solids would require in practice an uneconomic energy input. Therefore a limited size reduction by chopping long particles is used only to provide an uniform flow of the mixture into and through the digester. Up to now, the following methods of preparing the solids are introduced successfully in practice:

- chopping long straw or vegetable matter before mixing it with liquid manure by a pump in a preliminary pit;
- chopping long straw or solid manure containing long straw, and mixing it with liquid manure in a preliminary pit using a cutting pump;

with increasing viscosity of the fluid, the risk of separation of the different components of the mixture in the digester is decreased.

---

[1] The paper consists partially in an extract of a report prepared as a contribution to the CEC-Project "Assessment of biogas installation in Europe" (Baader, Kloss,1982)

In order to achieve an effective digestion of all components, coarse floatable particles must not reach the outlet of the digester in a shorter time than the designed retention time of the mixture.
Different systems of governing the flow of substrates containing floatable matter through the digester with low energy input meanwhile have been proved true.

ON-FARM EXPERIENCES

Vertical tank digester

Vertical tank-type digesters fitted with hydraulic (Fig. 1 and Fig. 2) or gas-injection (Fig. 3) stirring systems are working well (Wenzlaff, 1981; Gosch and co-workers, 1981) without blocking of floated material when fed with slurry of less than 5 % dry matter content and with loads of intensively chopped (< appr. 3 cm) straw or plant matter not higher than 3 kg d.m. to 1 m³ of slurry.

With cow manure of more than 8 % d.m. no floatation will occur and the added load of intensively chopped matter is limited by the viscosity of the fluid with which it can be pumped easily.

Forming of a scum layer is prevented by splashing fresh substrate (Fig. 1 and Fig.3) or recycled fluid (Fig. 1 and Fig. 2) at the surface of the liquid.

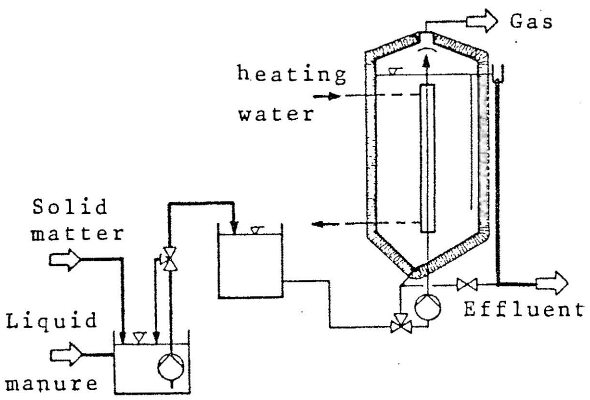

Fig. 1 Cylindrical vertical through-flown digester of 50 m³ volume; mixing by an external centrifugal pump (System AFAG)

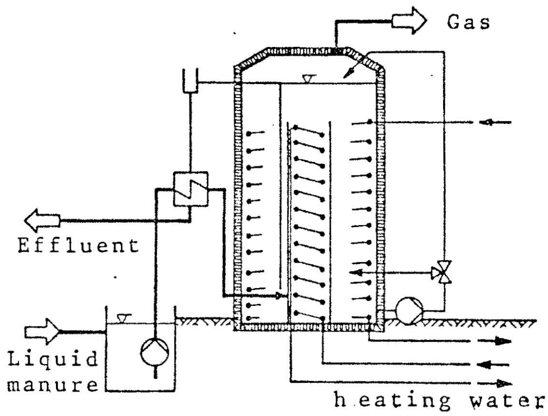

Fig. 2 Cylindrical vertical through-flown two-chambered digester of 95 m³ volume; mixing in the outer chamber by an external centrifugal pump (System OEKOTHERM)

Canal reactor

If higher quantities of straw or other plant matter are added to slurries of low dry matter content, then the tendency for the substrates to form floating layers is increased even further. Systems which, according to our current experience, guarantees an uninterrupted flow of even these difficult substrates as well as substrates of high total content of dry matter are horizontal digesters of the canal-type with horizontal stirring equipment, as for example shown in Fig. 4.
In this system previously introduced as "System Darmstadt" in farms in the 50's by Reinhold and Noak, Technical University Darmstadt, and described in detail by Stauss, 1956, the fluid is smoothly stirred transversally by means of slowly rotating paddles, which push floating matter back into the fluid. The outlet, positioned at the fluid level, is separated from the digestion compartment by a submerged wall. Floated matter which has reached this wall is delivered by the last paddle into the outlet section, where it leaves the digester with the effluent.
By means of circular plates formed as one turn of a screw and fitted at the rotating shaft, the uniform longitudinal flow of the fluid through the digester is achieved.

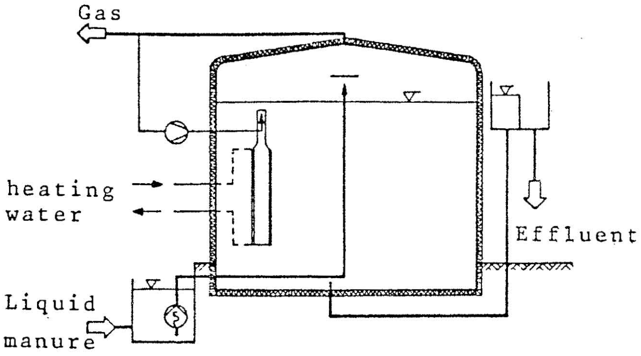

Fig. 3 Cylindrical vertical through-flown digester of 490 m³ volume; mixing by three gas-lift mixing installations (System HENZE-HARVESTORE)

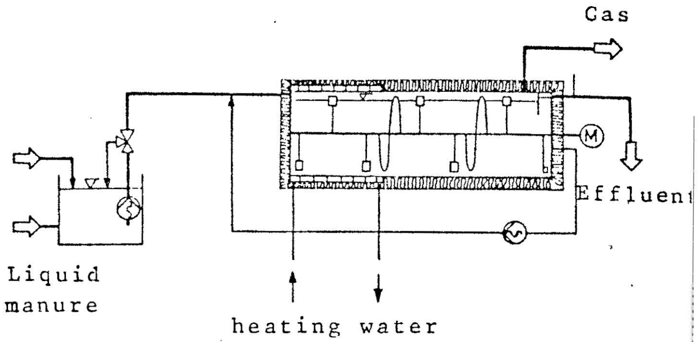

Fig. 4 Horizontal through-flown cylindrical digester of 62 m³ volume; slow mechanical stirring (System LIPP)

Dry matter contents in the mixture of about up to 12 % including portions of up to 10 kg d.m. slightly chopped straw added to 1 m³ of slurry can be handled in the canal-system (Rüprich 1982). However, the size of which seems to be limited of nearly 100 m³ volume by reason of increasing investment costs.
In some plants, which are mainly fed with liquid cattle manure, no stirring is used. The experiences hint that this is obviously possible without the gas yield altering noticeably. In these cases the dry matter content in the digester must be very high (≥ 8 %), otherwise settling and floating comes about in the tank. This disturbs the digester performance acutely.
For liquid pig or chicken manure there are no signs of similar plant simplification. The floating and settling layers must be brought under control in these plants. Further, attention must be paid to the inoculation of the fresh substrate with effluent rich in active microorganisms.

Multiple chamber reactor with gas displacement mixing

To meet the specific conditions required for the digestion of heterogeneous mixtures of sludges containing a considerable amount of fibrous coarse material and to prevent any problems with mechanical components the principle of mixing the fluid in the digester by using the expansion energy of the growing gas volume has proved to be a suitable solution. This principle, known as "System Berlin", was the first time realized and tested successfully in farm-scale by Ikonomoff and Gärtner, 1956.
In the multiple chamber digester (Fig. 5) hydraulic mixing is effected by an alternating stream of fluid which is displaced from the lower main chamber to an upper chamber by the increasing volume of gas which accumulates in the closed space above. When the gas is released from this space by means of a pressure-controlled and automatically operated valve, the fluid stored temporarily in the upper chamber flows back through the wide channel into the main chamber in a sudden surge which causes a considerable turbulence.

In this kind of digester the total dry matter content can reach approximately 10 %, included up to about 3 kg d.m. of chopped straw or other plant matter. The volumes of digesters already installed on farms range from 50 to 350 m³.

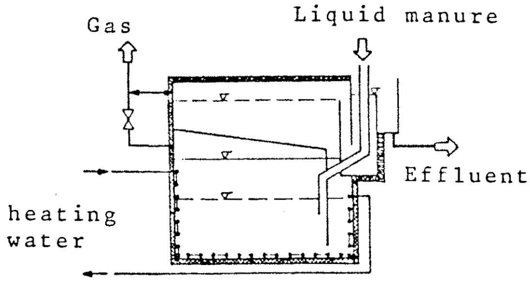

Fig. 5 Cubical multiple chambers digester of 250 m³ volume; hydraulically agitated by backflowing gas-displaced fluid (System BIMA)

EXPERIENCES WITH THE TOTALLY FILLED LOOP DIGESTER

A tank-type digester adapted to handling substrates with a high content of fibrous solids was tested successfully in medium size (6 m³ digester volume) and in full size (100 m³) since 3 years at the Institute of Technology in the Federal Research Centre of Agriculture at Braunschweig (Baader, 1981 a, 1981 b).

The substrate (as a mixture or - as shown in Fig. 6 - in separate streams of liquid and solids) is fed tangentially into the lower part of the digester being mixed with fluid taken off at the lowest point of the digester, and containing a high concentration of viable biomass.

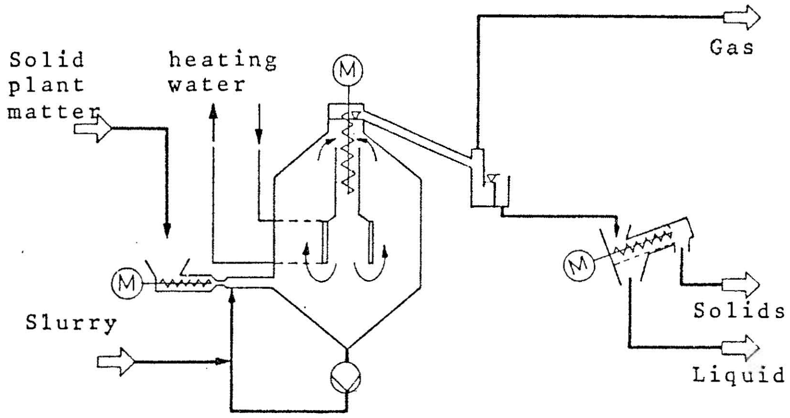

Fig. 6 Completely filled vertical flow digester, suitable for mixtures of slurry and fibrous matter installed in experimental plants (6 m³ and 100 m³) in the Agric. Res. Centre FAL at Braunschweig

In the completely filled tank the fluid is forced to flow in a loop by a slowly rotating screw installed in a central tube. Hence an uniform mixing is guaranteed in the loop section of the digester. The upstream of the fluid outside of the central tube ensures a fast releasing of the gas. The effluent and the gas leave the digester at its highest point and are separated subsequentely.

In enduring test runs by feeding different substrates of high tendency to separate by floatation, e.a. mixtures of low viscoseous organic slurries and coarse solid matter (straw, leaves, grass), and also high viscoseous mixtures of slurries (4,5 % d.m.) and wilted slightly chopped grass of up to 13 kg d.m./m³ (slurry), an uniform distribution of the components in the fluid and a controlled flow through the digester could achieved. The yields of methane reached in all cases the values known from laboratory scale digestability tests accomplished under comparable conditions.

CONCLUSIONS

In conventional tank-type digesters handling of substrates which tend to separate by floatation requires measures with a considerable need of installation and energy. Especially when the physical properties of the substrate are changing there is the risk of forming a floating layer followed by problems in discharging these solids. Whereas in digesters in which stirring is performed either - as in the multiple chamber digester - by turbulent backflowing fluid previously displaced by the expanding gas, or - as in the horizontal digester - by means of longitudinal slowly rotating paddle devices, liquid substrates of a broad range in their fluidmechanical properties can be handled. However, the size of such kind of digesters is limited by reason of the progressively increasing fixed costs.
According to the experiences obtained up to now with the completely filled loop digester this system seems to be a suitable solution with regard to the reliable through-flow of substrates of various fluidmechanical behaviour and rich in suspended floatable solids, which could be realized also in larger digesters with comparatively favourable costs.

REFERENCES

Baader, W. (1981). Das FAL-Biogasprojekt. Grundlagen Landtechnik, 31, 37-76.
Transl. by N.M. Reilly (1981). The FAL-Biogas-Project. Translation T 479, NIAE, Silsoe, Bedford.

Baader, W. (1981 b). Erste Erfahrungen mit einem vollständig gefüllten vertikal durchströmten Biogasgenerator. Grundlagen Landtechnik, 31, 50-55.
Transl. by N.M. Reilly (1981). First experiences with a completely filled vertical flow anaerobic digester. Translation T 476, NIAE, Silsoe, Bedford.

Baader, W. and R. Kloss(1982). Assessment of biogas installations in the Federal Republic of Germany. Report to the CEC-Project No. ES-E-R-051-D(N), Braunschwe

Gosch, A., G. Agostini and W. Weber (1981). Anaerobe Behandlung von Rindergülle (Anaerobic treatment of liquid cattle manure). Landtechnik, 36, 50-53.

Ikonomoff, S.D. and A. Gärtner (1956). Faulschlamm-Gasanlage "System Berlin". Städtehygiene, 7, 110-113.

Rüprich, W. (1982). Verfahrenssysteme zur Faulung tierischer Exkremente und pflanzlicher Abfallstoffe in der Landwirtschaft. In W.J. Bartz (Ed.), Biogasanlagen. Kontakt & Studium, Vol. 103, Expert Verlag, Grafenau. Chap. 3.2 pp. 117-131.

Stauss, W. (1956). Der heutige Stand der Biogasgewinnung aus landwirtschaftlichen organischen Stoffen (State of the art of biogas production from agricultural organic matter). In H. Liebmann (Ed.), Münchner Beiträge zur Abwasser-, Fischerei- und Flußbiologie, Vol. 3, pp.